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U.S. PATENT APPLICATION

FOR

HIGH HC REFERENCE LAYER STRUCTURE FOR SELF-PINNED GMR HEADS

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RELATED APPLICATION

This application is related to a U.S. Patent Application filed concurrently herewith entitled "Self-Pinned CPP Sensor Using Fe/Cr/Fe Structure" by the same inventor and assigned to a common assignee, the Patent Application being herein incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to magnetic heads, and more particularly, this invention relates to read heads having a high coercivity structure.

BACKGROUND OF THE INVENTION

The heart of a computer is a magnetic disk drive which includes a rotating magnetic disk, a slider that has read and write heads (also called writers and sensors), a suspension arm above the rotating disk and an actuator arm that swings the suspension arm to place the read and write heads over selected circular tracks on the rotating disk. The suspension arm biases the slider into contact with the surface of the disk when the

disk is not rotating but, when the disk rotates, air is swirled by the rotating disk adjacent an air bearing surface (ABS) of the slider causing the slider to ride on an air bearing a slight distance from the surface of the rotating disk. When the slider rides on the air bearing the write and read heads are employed for writing magnetic impressions to and reading magnetic signal fields from the rotating disk. The read and write heads are connected to processing circuitry that operates according to a computer program to implement the writing and reading functions.

In high capacity disk drives, magnetoresistive (MR) read sensors, commonly referred to as MR heads, are the prevailing read sensors because of their capability to read data from a surface of a disk at greater track and linear densities than thin film inductive heads. An MR sensor detects a magnetic field through the change in the resistance of its MR sensing layer (also referred to as an "MR element") as a function of the strength and direction of the magnetic flux being sensed by the MR layer.

The conventional MR sensor operates on the basis of the anisotropic magnetoresistive (AMR) effect in which an MR element resistance varies as the square of the cosine of the angle between the magnetization in the MR element and the direction of sense current flow through the MR element. Recorded data can be read from a magnetic medium because the external magnetic field from the recorded magnetic medium (the signal field) causes a change in the direction of magnetization of the MR element, which in turn causes a change in resistance of the MR element and a corresponding change in the sensed current or voltage.

Another type of MR sensor is the giant magnetoresistance (GMR) sensor manifesting the GMR effect. In GMR sensors, the resistance of the GMR sensor varies as

a function of the spin-dependent transmission of the conduction electrons between ferromagnetic layers separated by a non-magnetic layer (spacer) and the accompanying spin-dependent scattering which takes place at the interface of the ferromagnetic and non-magnetic layers and within the ferromagnetic layers.

GMR sensors using only two layers of ferromagnetic material (e.g., Ni-Fe) separated by a layer of non-magnetic material (e.g., copper) are generally referred to as spin valve (SV) sensors. In an SV sensor, one of the ferromagnetic layers, referred to as the pinned layer (reference layer), has its magnetization typically pinned by exchange coupling with an antiferromagnetic (e.g., NiO or Fe-Mn) layer. The pinning field generated by the antiferromagnetic layer should be greater than demagnetizing fields (about 200 Oe) at the operating temperature of the SV sensor (about 120° C) to ensure that the magnetization direction of the pinned layer remains fixed during the application of external fields (e.g., fields from bits recorded on the disk). The magnetization of the other ferromagnetic layer, referred to as the free layer, however, is not fixed and is free to rotate in response to the field from the recorded magnetic medium (the signal field). U.S. Pat. No. 5,206,590 granted to Dieny et al., incorporated herein by reference, discloses a SV sensor operating on the basis of the GMR effect.

An exemplary high performance read head employs a spin valve sensor for sensing the magnetic signal fields from the rotating magnetic disk. FIG. **1A** shows a prior art SV sensor **100** comprising a free layer (free ferromagnetic layer) **110** separated from a pinned layer (pinned ferromagnetic layer) **120** by a non-magnetic, electrically-conducting spacer layer **115**. The magnetization of the pinned layer **120** is fixed by an antiferromagnetic (AFM) layer **130**.

FIG. **1B** shows another prior art SV sensor **150** with a flux keepered configuration. The SV sensor **150** is substantially identical to the SV sensor **100** shown in FIG. **1A** except for the addition of a keeper layer **152** formed of ferromagnetic material separated from the free layer **110** by a non-magnetic spacer layer **154**. The keeper layer **152** provides a flux closure path for the magnetic field from the pinned layer **120** resulting in reduced magnetostatic interaction of the pinned layer **120** with the free layer **110**. U.S. Pat. No. 5,508,867 granted to Cain et al. discloses a SV sensor having a flux keepered configuration.

Another type of SV sensor is an antiparallel (AP)-pinned SV sensor. In AP-Pinned SV sensors, the pinned layer is a laminated structure of two ferromagnetic layers separated by a non-magnetic coupling layer such that the magnetizations of the two ferromagnetic layers are strongly coupled together antiferromagnetically in an antiparallel orientation. The AP-Pinned SV sensor provides improved exchange coupling of the antiferromagnetic (AFM) layer to the laminated pinned layer structure than is achieved with the pinned layer structure of the SV sensor of FIG. **1A**. This improved exchange coupling increases the stability of the AP-Pinned SV sensor at high temperatures which allows the use of corrosion resistant antiferromagnetic materials such as NiO for the AFM layer.

Referring to FIG. **2A**, an AP-Pinned SV sensor **200** comprises a free layer **210** separated from a laminated AP-pinned layer structure **220** by a nonmagnetic, electrically-conducting spacer layer **215**. The magnetization of the laminated AP-pinned layer structure **220** is fixed by an AFM layer **230**. The laminated AP-pinned layer structure **220** comprises a first ferromagnetic layer **226** and a second ferromagnetic layer **222** separated

by an antiparallel coupling layer (APC) **224** of nonmagnetic material. The two ferromagnetic layers **226, 222** (FM_1 and FM_2) in the laminated AP-pinned layer structure **220** have their magnetization directions oriented antiparallel, as indicated by the arrows **227, 223** (arrows pointing out of and into the plane of the paper respectively).

A key requirement for optimal operation of an SV sensor is that the pinned layer should be magnetically saturated perpendicular to the air bearing surface. Lack of magnetic saturation in the pinned layer leads to reduced signal or dynamic range. Factors leading to a loss of saturation include demagnetizing fields at the edge of the pinned layer, magnetic fields from recorded data and from longitudinal biasing regions, current induced fields and the coupling field to the free layer.

Analysis of the magnetic state of pinned layers in small sensors (a few microns or less in width), reveals that due primarily to the presence of large demagnetizing fields at the sensor edges the magnetization is not uniform over the area of the pinned layer. FIG. **2B** shows a perspective view of an SV sensor **250**. The SV sensor **250** is formed of a sensor stripe **260** having a front edge **270** at the ABS and extending away from the ABS to a rear edge **272**. Due to the large demagnetizing fields at the front edge **270** and the rear edge **272** of the sensor stripe **260**, the desired perpendicular magnetization direction is achieved only at the center portion **280** of the pinned layer stripe, while the magnetization tends to be curled into a direction parallel to the ABS at the edges of the stripe. The extent of these curled regions is controlled by the magnetic stiffness of the pinned layer.

As mentioned above, prior art AP-Pinned SV sensors use an AFM in order to pin the pinned layer magnetization so that the pinned layers do not move around when the

head is reading data from the disk, upon application of external magnetic fields, etc. The AFM layers are typically very thick, on the order of 150-200Å. Due to the large overall thickness, such sensors are typically not practical for use in applications where a thin head is desirable.

What is needed is an AP-Pinned SV sensor having a smaller overall thickness.

SUMMARY OF THE INVENTION

The present invention overcomes the drawbacks and limitations described above by providing a magnetic head having a free layer, an antiparallel (AP) pinned layer structure spaced apart from the free layer, and a high coercivity structure positioned towards the AP pinned layer structure on an opposite side thereof relative to the free layer. The high coercivity structure pins a magnetic orientation of the AP pinned layer structure.

The AP pinned layer structure includes at least two pinned layers having magnetic moments that are self-pinned antiparallel to each other, the pinned layers being separated by an AP coupling layer. Preferably, the pinned layers of the AP pinned layer structure are formed of CoFe. In one embodiment, a magnetic thickness of the high coercivity structure and the pinned layer of the AP pinned layer structure positioned closest thereto is about equal to a magnetic thickness of the pinned layer of the AP pinned layer structure positioned farthest from the high coercivity structure.

In a preferred embodiment, the high coercivity structure includes a layer of CoPtCr or other high coercivity material. In this embodiment, the high coercivity structure further includes an amorphous layer positioned between the layer of CoPtCr and the AP pinned layer structure. The amorphous layer can be formed of CoFeX, where X is selected from a group consisting of Nb, Zn and Hf. If necessary to aid in proper growth of the CoPtCr (or other material),a seed layer of magnetic material can be formed under the CoPtCr (or other material).

The head described herein may form part of a GMR head, a CPP GMR sensor, a CIP GMR sensor, a CPP tunnel valve sensor, etc. for use in a magnetic storage system.

Other aspects and advantages of the present invention will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

FIG. **1A** is an air bearing surface view, not to scale, of a prior art spin valve (SV) sensor.

FIG. **1B** is an air bearing surface view, not to scale, of a prior art keepered SV sensor.

FIG. **2A** is an air bearing surface view, not to scale, of a prior art AP-Pinned SV sensor.

FIG. **2B** is a perspective view, not to scale, of a prior art AP-Pinned SV sensor.

FIG. **3** is a simplified drawing of a magnetic recording disk drive system.

FIG. **4** is a partial view of the slider and a merged magnetic head.

FIG. **5** is a partial ABS view, not to scale, of the slider taken along plane **5-5** of FIG. **4** to show the read and write elements of the merged magnetic head.

FIG. **6** is an enlarged isometric illustration, not to scale, of the read head with a spin valve sensor.

FIG. **7** is an ABS illustration of a CPP GMR sensor, not to scale, according to an embodiment of the present invention.

FIG. **8** is an ABS illustration of a CPP tunnel valve sensor, not to scale, according to an embodiment of the present invention.

FIG. 9 is an ABS illustration of a CIP GMR sensor, not to scale, according to an embodiment of the present invention.

<u>Best Mode for Carrying Out the Invention</u>

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **3**, there is shown a disk drive **300** embodying the present invention. As shown in FIG. **3**, at least one rotatable magnetic disk **312** is supported on a spindle **314** and rotated by a disk drive motor **318**. The magnetic recording on each disk is in the form of an annular pattern of concentric data tracks (not shown) on the disk **312**.

At least one slider **313** is positioned near the disk **312**, each slider **313** supporting one or more magnetic read/write heads **321**. More information regarding such heads **321** will be set forth hereinafter during reference to FIG. **4**. As the disks rotate, slider **313** is moved radially in and out over disk surface **322** so that heads **321** may access different tracks of the disk where desired data are recorded. Each slider **313** is attached to an actuator arm **319** by means way of a suspension **315**. The suspension **315** provides a slight spring force which biases slider **313** against the disk surface **322**. Each actuator arm **319** is attached to an actuator means **327**. The actuator means **327** as shown in FIG. **3** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **329**.

During operation of the disk storage system, the rotation of disk **312** generates an air bearing between slider **313** and disk surface **322** which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension **315** and supports slider **313** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **329**, such as access control signals and internal clock signals. Typically, control unit **329** comprises logic control circuits, storage means and a microprocessor. The control unit **329** generates control signals to control various system operations such as drive motor control signals on line **323** and head position and seek control signals on line **328**. The control signals on line **328** provide the desired current profiles to optimally move and position slider **313** to the desired data track on disk **312**. Read and write signals are communicated to and from read/write heads **321** by way of recording channel **325**.

The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. **3** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. **4** is a side cross-sectional elevation view of a merged magnetic head **400**, which includes a write head portion **402** and a read head portion **404**, the read head portion employing a dual spin valve sensor **406** of the present invention. FIG. **5** is an ABS view of FIG. **4**. The spin valve sensor **406** is sandwiched between nonmagnetic electrically insulative first and second read gap layers **408** and **410**, and the read gap

layers are sandwiched between ferromagnetic first and second shield layers **412** and **414**. In response to external magnetic fields, the resistance of the spin valve sensor **406** changes. A sense current (I_s) conducted through the sensor causes these resistance changes to be manifested as potential changes. These potential changes are then processed as readback signals by the processing circuitry **329** shown in FIG. **3**.

The write head portion **402** of the magnetic head **400** includes a coil layer **422** sandwiched between first and second insulation layers **416** and **418**. A third insulation layer **420** may be employed for planarizing the head to eliminate ripples in the second insulation layer caused by the coil layer **422**. The first, second and third insulation layers are referred to in the art as an "insulation stack". The coil layer **422** and the first, second and third insulation layers **416**, **418** and **420** are sandwiched between first and second pole piece layers **424** and **426**. The first and second pole piece layers **424** and **426** are magnetically coupled at a back gap **428** and have first and second pole tips **430** and **432** which are separated by a write gap layer **434** at the ABS. Since the second shield layer **414** and the first pole piece layer **424** are a common layer this head is known as a merged head. In a piggyback head an insulation layer is located between a second shield layer and a first pole piece layer. First and second solder connections (not shown) connect leads (not shown) from the spin valve sensor **406** to leads (not shown) on the slider **313** (FIG. **3**), and third and fourth solder connections (not shown) connect leads (not shown) from the coil **422** to leads (not shown) on the suspension.

FIG. **6** is an enlarged isometric ABS illustration of the read head **400** shown in FIG. **4**. The read head **400** includes the spin valve sensor **406**. First and second hard bias and lead layers **602** and **604** are connected to first and second side edges **606** and **608** of

the spin valve sensor. This connection is known in the art as a contiguous junction and is fully described in U.S. Pat. 5,018,037 which is incorporated by reference herein. The first hard bias and lead layers **602** include a first hard bias layer **610** and a first lead layer **612** and the second hard bias and lead layers **604** include a second hard bias layer **614** and a second lead layer **616**. The hard bias layers **610** and **614** cause magnetic fields to extend longitudinally through the spin valve sensor **406** for stabilizing the magnetic domains therein. The spin valve sensor **406** and the first and second hard bias and lead layers **602** and **604** are located between the nonmagnetic electrically insulative first and second read gap layers **408** and **410**. The first and second read gap layers **408** and **410** are, in turn, located between the ferromagnetic first and second shield layers **412** and **414**.

The present invention provides a new sensor structure having a thinner in-stack bias structure together with reduced current shunting to optimize dr/R. Many types of heads can use the structure described herein, and the structure is particularly adapted to a CPP GMR sensor, a CIP GMR sensor, and a CPP tunnel valve sensor. In the following description, the width of the layers (W) refers to the track width. The sensor height is in a direction into the face of the paper. Unless otherwise described, thicknesses of the individual layers are taken perpendicular to the plane of the associated layer, and are provided by way of example only and may be larger and/or smaller than those listed. Similarly, the materials listed herein are provided by way of example only, and one skilled in the art will understand that other materials may be used without straying from the spirit and scope of the present invention.

<u>CPP GMR</u>

FIG. **7** depicts an ABS view of a CPP GMR sensor **700** according to one embodiment. "CPP" means that the sensing current (I_s) flows from one shield to the other shield in a direction perpendicular to the plane of the layers forming the sensor **700**.

As shown in FIG. **7**, a first shield layer (S1) **702** is formed on a substrate (not shown). The first shield layer **702** can be of any suitable material, such as permalloy (NiFe).

Seed layers are formed on the first shield layer **702**. The seed layers aid in creating the proper growth structure of the layers above them. Illustrative materials formed in a stack from the first shield layer **702** are a layer of Ta (SL1) **704**, a layer of NiFeCr (SL2) **706**, and a layer of NiFe (SL3) **708**. Illustrative thicknesses of these materials are Ta (30Å), NiFeCr (20Å), and NiFe (8Å). Note that the stack of seed layers can be varied, and layers may be added or omitted based on the desired processing parameters.

A free layer (FL) **710** is formed above the seed layers **704-708**. The magnetic moment of the free layer **710** is soft and so is susceptible to reorientation from external magnetic forces, such as those exerted by data on disk media. The relative motion of magnetic orientation of the free layer **710** when affected by data bits on disk media creates variations in the sensing current flowing through the sensor **700**, thereby creating the signal. Exemplary materials for the free layer **710** are CoFe, a CoFe/NiFe stack, etc. An illustrative thickness of the free layer **710** is about 10-40Å.

The magnetic orientation of the free layer **710** must be preset during manufacture, otherwise the orientation will be unstable and could move around at random, resulting in a "scrambled" or noisy signal. This instability is a fundamental property of soft

materials, making them susceptible to any external magnetic perturbations. Thus, the magnetic orientation of the free layer **710** should be stabilized so that when its magnetic orientation moves, it consistently moves around in a systematical manner rather than a random manner. The magnetic orientation of the free layer **710** should also be stabilized so that it is less susceptible to reorientation, i.e., reversing. Usually hard magnet layers are placed adjacent to the free layer edges to stabilize the free layer (not shown in FIG. 7).

A spacer layer (SP) **712** is formed above the free layer **710**. Illustrative materials for the spacer layer **712** are Ta, Ru, Ta/Ru stack, Cu, etc. An exemplary thickness of the spacer layer **712** is about 20-30Å.

Then an antiparallel (AP) pinned layer structure **722** is formed above the spacer layer **712**. As shown in FIG. **7**, first and second AP pinned magnetic layers, (AP1) and (AP2) **724**, **726**, are separated by a thin layer of an antiparallel coupling (APC) material **728** such that the magnetic moments of the AP pinned layers **724**, **726** are self-pinned antiparallel to each other. The pinned layers **724**, **726** have a property known as magnetostriction. The magnetostriction of the pinned layers **724**, **726** is very positive. The sensor **700** is also under compressive stresses because of its geometry at the ABS, and the configuration of the layer is such that it produces very large compressive stress. The combination of positive magnetostriction and compressive stress causes the pinned layers **724**, **726** to develop a magnetic anisotropy that is in a perpendicular direction to the track width. This magnetic coupling through the Ru spacer causes the pinned layers **724**, **726** to have antiparallel-oriented magnetizations.

In the embodiment shown in FIG. **7**, the preferred magnetic orientation of the pinned layers **724**, **726** is for the first pinned layer **724**, into the face of the structure depicted (perpendicular to the ABS of the sensor **700**), and out of the face for the second pinned layer **726**. Illustrative materials for the pinned layers **724**, **726** are $CoFe_{10}$ (90% Co, 10% Fe), $CoFe_{50}$ (50% Co, 50% Fe), etc. separated by an antiparallel coupling layer **728** of Ru. Illustrative thicknesses of the first and second pinned layers **724**, **726** are between about 10Å and 25Å. The Ru layer **728** can be about 5-15Å, but is preferably selected to provide a saturation field above about 10 KOe. In a preferred embodiment, each of the pinned layers **724**, **726** is about 18Å with an Ru layer **728** therebetween of about 8Å.

In typical heads, the AP pinned layer structure **722** is stabilized by placement of an antiferromagnetic (AFM) layer above the pinned layer structure **722**. The AFM layer pins the AP pinned layer structure **722** so that the pinned layers **724**, **726** do not move around when disk is reading data from disk, upon application of external magnetic fields, etc. However, as mentioned above, AFM layers are very thick, typically about 150-200A. If the designer wants to fit the sensor into small gap, use of thick AFM layers is not practical.

To reduce the overall thickness of the sensor **700** while providing the desired stabilizing effect, a high coercivity structure **730** is formed above the pinned layer structure **722**. The high coercivity structure **730** pins the magnetic orientation of the second pinned layer **726**, stabilizing the overall pinned layer structure **722**.

The high coercivity structure **730** includes a layer of high coercivity (HC) material **736**. The preferred material for the high coercivity layer **736** is CoPtCr, though

other hard magnet materials can also be used. CoPtCr has a coercivity of greater than about 1000 Oe, and is sometimes used in hard disk media. This high coercivity pins the second pinned layer **726**. A preferred thickness of the high coercivity layer **736** is about 10-30Å, ideally about 10-20Å.

However, if CoPtCr is placed directly on top of CoFe, the coercivity of the CoPtCr drops to about 50 Oe. To maintain the high coercivity of CoPtCr, an amorphous layer (AL) **732** is formed between the CoFe second pinned layer **726** and the high coercivity layer **736** by any suitable material, such as sputtering (ion beam deposition (IBD), plasma vapor deposition (PVD), etc.). The amorphous layer **732** should be formed of a magnetic material so that the high coercivity layer **736** couples to the second pinned layer **726**. Preferred materials from which the amorphous layer **732** is formed include CoFeX, where X = Nb, Zn, and/or Hf. Adding about 5-10% of any of these X materials into CoFe makes it amorphous. An illustrative thickness of the amorphous layer **732** is about 5-20Å, ideally about 10Å.

CoPtCr has a crystalline structure. However, the amorphous layer **732** has no ordered structure, making formation of the ordered crystalline CoPtCr difficult. A fresh surface above the amorphous layer **732** may be necessary in order to obtain proper physical growth of CoPtCr structure. To allow the CoPtCr to grow properly, a seed layer (SL4) **734** can be added between the amorphous layer **732** and the high coercivity layer **736**. Preferred materials for the seed layer **734** are FeCr, Fe, or other magnetic material. An illustrative thickness of the seed layer **734** is about 5-25Å, ideally about 10-20Å.

A cap (CAP) **738** is formed above the high coercivity layer **736**. Exemplary materials for the cap **738** are Ta, Ta/Ru stack, etc. An illustrative thickness of the cap **738** is 20-40Å.

A second shield layer (S2) **740** is formed above the cap **738**. An insulative material **742** such as Al_2O_3 is formed on both sides of the sensor **700**.

Note that in some embodiments, the first pinned layer **724** (e.g., of CoFe) generates magnetoresistance with the Cu spacer layer **712**. Because magentoresistance is a function of magnetic thickness, and because the second pinned layer **726** (e.g., of CoFe) and the high coercivity structure **730** above it are magnetic, it is desirable to obtain a total magnetic thickness of the second pinned layer **726** and the high coercivity structure **730** comparable to that of the first pinned layer. Thus, the second pinned layer **726** is preferably thinner than the first pinned layer **724** to reduce canceling of the magnetoresistive signal by the second pinned layer **726**. This results in a larger net magnetoresistive signal.

One practicing the invention can determine the appropriate magnetic thickness of the layers using the following equation:

$$\textit{Magnetic thickness} = M \times T \qquad \text{Equation 1}$$

where:

M = magnetization = magnetic moment per unit volume (emu/cm^3);

T = physical thickness (cm); and

emu = electromagnetic unit.

CPP Tunnel Valve

FIG. **8** depicts an ABS view of a CPP tunnel valve sensor **800** according to one embodiment. The CPP tunnel valve sensor **800** generally has the same configuration as the structure shown in FIG. **7**, except that the spacer layer **712** is formed of a dielectric barrier material, such as, Al_2O_3, AlO_x, MgO_x, etc. The spacer layer **712** is very thin such that the electric current passing through the sensor **800** "tunnels" through the spacer layer **712**. An illustrative thickness of the spacer layer **712** is 3-6Å.

CIP GMR

FIG. **9** depicts an ABS view of a CIP GMR sensor **900** according to one embodiment. "CIP" means that the sensing current (I_s) flows from in a direction parallel to or "in" the plane of the layers forming the sensor **900**. The CIP GMR sensor **900** generally has the same configuration as the structures shown in FIGS. **7** and **8**, except that leads **902** of conventional materials and thicknesses are formed on opposite sides of the sensor **900** and the sensor **900** is sandwiched between an insulative material (G1), (G2) **904, 906**. Another important difference is that current flows across the track width as opposed to perpendicular to the track width. Because the current can flow through all of the layers, it is desirable to reduce the amount of current flowing through the AP pinned layer structure **722** so that more current flows through the free layer **710**. To achieve this, the second pinned layer **726** is preferably smaller than the first pinned layer **724** to reduce shunting of the current.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. For example, the structures and methodologies presented herein are generic in their application to all MR heads, AMR heads, GMR heads, spin valve heads, etc. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.